The dynamics of research networks in Brite-Euram

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Abstract

Network formation within the BRITE-EURAM program is investigated. We describe the role of the hub of the network, which is defined as the set of main contractors that account for most of the participations. We study the effects that the conflict of objectives within European research funding between pre–competitive research vs. European cohesion has on the formation of networks and on the relationship between different partners of the network.

A panel data set is constructed including the second and third framework of the Brite–Euram program. A model of joint production of research results is used to test for changes in the behavior of partners within the two frameworks.

The main findings are that participations are very concentrated, that is a small group of institutions account for most of the participations, but going from the second to the third framework the presence of subcontractors and single participants increases substantially. This result is reinforced by the fact that main contractors receive smaller spill-ins within networks, but spill-ins increase from the second to the third framework.

JEL Subject Classification: Positive Analysis of Policy–Making and Implementation (D78), National Government Expenditures and Related Policies: General (H50), O32 (Management of Technological Innovation and R& D) and O38 (Governent Policy).

1 Introduction

The European Commission (EC) has been pursuing an active policy of funding research since its inception. The EC R& D projects intend to have strategic character, i.e. they are aimed at changing the objectives and methods of research, rather than simply augmenting the search for new knowledge. On the one hand the EC has the objective of improving the competitivity of the European industry by the invention and development of new processes and products, and on the other hand it wants to trigger projects that would not be initiated without this funding. Another goal is to promote links between academic and industrial research. These objectives have to be balanced out with the goal of European cohesion, trying to expand research capabilities to institutions from underdeveloped regions.

This wide and diverse set of objectives is not always internally coherent. Especially conflicting are the attempts to foster pre-competitive research and being at the same time market oriented, as it is often the case for industry–oriented R & D research programs. In some of these programs the funding effort is supposed to contribute to the process of European cohesion, but at the same time the projects must be selected on technical and scientific merit alone. Another typical conflict arises from the fact that picking a mix of institutions with different research capabilities contributes to the diffusion of new techniques and results and therefore improves the research capabilities of the European scientific community taken as a whole, while funding the most reputed institutions allows the programs to present a high research productivity in the short run.

These conflicts can be studied by means of a simple framework. The funding agency, in this case the EC, demands scientific results and supplies funds for research, while the research units demand funds and supply results. We do not have information about scientific results, but we have very detailed information on the funding effort by the European Commission and about the participation of research units in the Brite–Euram program.

In this paper we study the effects of the funding effort by the European Commission on both the supply and the demand of funds, and on the participation of research units in the networks formed. We study the contracts signed under the Brite Euram program for the second and third framework. Particular attention is given to the hub of the network, that is main contractors or originators of networks that span different networks and different years, accounting for a substantial proportion of the total participation in networks. We use a model of coalition formation and spill–ins within the coalition (see Olson and Zeckhauser, 1966, or Sandler and Murdoch, 1990) to formulate an empirical model and analyze the effects of EC funding on the networks, by assessing how the role of the hub and the evolution of the networks have changed along the two frameworks.

The paper is organized as follows: In section 2 we present a theoretical model of network interaction. We proceed in section 3 by describing the main features of the Brite/Euram program. This allows us to identify some dynamic features of the contracts signed, which we present in section 4. The theoretical model is finally implemented empirically and tested in section 5. We conclude in section 6.

2 A model of research coalitions

We start by proposing a model of network interaction, based on similar models that have been proposed in the literature for the production of joint public goods [1].

We consider the networks as coalitions of researchers which engage in research activities that provide both private knowledge output, which is institution–specific, and public knowledge output, which is network–specific.

Let q^i be the private knowledge and k^i the public knowledge produced by member i of a network, and l^i the general research activities provided by the i–th component of the network. The joint production relationships for q^i and k^i are given by:

$$(1) \quad q^i = f_i(l^i),$$

and

$$(2) \quad k^i = g_i(l_i),$$

where both $f_i(\cdot)$ and $g_i(\cdot)$ are assumed to be twice continously differentiable and concave.

Consider the total public knowledge produced within the network, K. Since K is a purely public good within the network, each partner receives the knowledge that he/she produces, k^i, and the common knowledge spilled in from the rest of the network, $\tilde{K}^i = \sum_{j \neq i} k^i$. Hence, each partner receives:

$$K = \tilde{K}^i + k^i.$$

If the network has n members, the knowledge that spills over to participant i

[1] For a survey of this kind of models see Sandler (1992), chapters 4 and 5. The version that we present here follows closely Sandler and Murdoch (1990).

derives from the aggregate activities $\tilde{L}^i$ of the $n-1$ partners according to the following relation:

$$(3) \quad \tilde{K}^i = s(\tilde{L}^i), \qquad s' > 0, \qquad s'' < 0.$$

We model the choice of network activity by the utility function of a representative member of the network (network members do not need to be identical):

$$(4) \quad u^i = u^i(x^i, q^i, \tilde{K}^i + k^i),$$

where x^i represents the nummeraire, or the choice of other goods (income effects are assumed to be negligible).

Substituting equations (1), (2) and (3) into (4), we obtain:

$$u^i = u^i(x^i,\ f_i(l^i), g_i(l^i) + s(\tilde{L}^i)) = v^i(x_i, l^i|\tilde{L}^i).$$

There are two ways of obtaining demand functions from this model: 1) the Nash–Cournot equilibrium concept implies that each agent chooses the level of activity in order to maximize his or her utility subject to an income budget constraint and to the prevailing contributions of public knowledge from the rest of the network, $\tilde{L}^i = \sum_{j\neq i} l^j$ and 2) the Lindahl equilibrium concept, that assumes that network members communicate and exchange information concerning the level of the public knowledge that they are going to share in the network, but meet the costs by individualized cost shares (the shares must sum to one, so that costs are covered).

The maximization problem for the i-th agent in the case of Nash–Cournot equilibrium can be written as:

$$\max_{x^i, L^i} \{v^i(x^i, l^i|\tilde{L}^i)|I^i + p\tilde{L}^i = p_x x^i + pl^i\},$$

where p_x and p are the prices of x and L respectively, and $I^i + p\tilde{L}^i$ is income.

The solution to this maximization problem is the demand function for total network research activity by institution i:

$$(5) \quad l^i_N = l^i_N(I^i + pl^i, p_y, p, \tilde{l}^i).$$

where the subscript N stands for Nash-Cournot. The network demand for common knowledge depends on prices, income and the level of knowledge spill-ins.

In equilibrium all members of the network will demand the equilibrium level of total network research activity, that is $l^e = l_N^i$ for all i.

For a research coalition, we can also take into account that the search for scientific results can be considered a race against other research teams, and therefore the research expenditure of other similar networks can be considered as a "threat", T, for any given coalition of researchers. If we condition all the analysis to this threat, we will find this new variable in the demand function:

$$(6) \quad l_N^i = l_N^i(I^i + pl^i, p_y, p, \tilde{l}^i, T).$$

In the case of Lindahl equilibrium concept, each partner in the network is assumed to have preferences represented by the following utility function:

$$(7) \quad u^i = u^i(x^i, q^i, K),$$

where again

$$(8) \quad K = \tilde{K}^i + k^i$$

and the joint production relationships are

$$(9) \quad q^i = f_i(L)$$

and

$$(10) \quad K = g(L).$$

In this case the total level of the collective research activity, k, produces both the private and public knowledge experienced by each partner of the network. The Lindahl equilibrium concepts implies a cooperative game, and therefore the partners choose the equilibrium level of joint research. Each partner contributes a private effort to the relationship and is assigned a share in the aggregate cost of the project, θ^i.

Substituting (8), (9) and (10) into (7) and taking into account the budget constraint:

$$p_x x^i + \theta^i pL = I^i$$

allows us to formulate the maximization problem for the i-th partner as follows:

$$\max_{x^i, L}\{U^i(x^i, L) | p_x x^i + \theta^i pL = I^i\}$$

The solution to this problem gives the following demand functions:

$$(11) \quad L_H^i = L_H^i(I^i, p_y, \theta^i p, T),$$

where H stands for Lindahl.

We will base our estimable equations on equation (6) for the Nash-Cournot case and equation (11) for the Lindahl case. We will assume that the total research activity assumed by each network can be measured by the EC contribution, while the total income that each participant has, is given by the total cost committed to the project. We do not have information about knowledge prices, but assuming that prices of the rest of goods and knowledge prices move together, and taking into account the 0-degree homogeneity of the demand functions, we can formulate the demand functions only in terms of income and spill-ins, by deflating all variables by a common price deflator.

We will use this model to investigate the demand functions for EC contribution of different types of participants at different moments in time. It is necessary first to describe what are the relevant types of participants, and how participation has evolved over Framework 2 and 3 of the Brite–Euram program.

3 The BRITE - EURAM shared-cost projects

The following analysis focuses on the contracts signed in the period 1989–1993 in the BRITE-EURAM I and BRITE-EURAM II (henceforth in general BE) programs [2]. BE represents a particularly suitable program for our purpose for the following reasons. First, its technological and sectorial foci represents a heterogeneous set of participants (Commission, 1992b: p.41; Commission, 1993: p.10). Second, the sectorial orientation involves not only applied and development work, but also more basic research with industrial applicability. Third, if we consider both the number of participations and the funding level for shared cost actions, BE is the second most important program throughout this period.

We obtained the original data set from the DGXII of the EC. The contracts signed were respectively 352, with 1783 participations[3], in the Second Framework (SF) and 703, with 2056 participations, in the Third Framework (TF). For each

[2] The contracts signed under RAW and AERONAUTICS are not included.

[3] In this part of the article for participation we mean a contractor of any category, including also institutions involved in time/contribution amendments. In the statistics, instead, participations come only from contractors involved in shared–cost actions.

Table 1: Participations in the two frameworks, break down by type of cost

Cost Type 2nd.	Framework	3rd. Framework	Total
ECO	1,302 (73.2%)	1,221 (73.5%)	2,523 (73.3%)
MAR	476 (26.8%)	441 (26.5%)	916 (26.7%)
Total	1,778	1,662	3,440

Source: Elaboration EC Data

contract we were provided with the following information: title of the project, duration of the contract, cost and EC contribution[4], participants names and locations, and participants position in the network (main contractor, secondary contractor, subcontractor, etc.). Instead, we did not succeed in obtaining information on the organizations: type of institution (large enterprise, small-medium enterprise, university, research organization, etc.) and its dimension. As we were interested in the research network, we decided to focus our analysis only on shared-cost collaborative research projects. Therefore, we excluded from our database the following types of contracts: feasibility award, first step CRAFT, concerted action, other 'like-grant' action, and time ammendments. Instead, we considered the institutions involved in contribution ammendments as normal contractors taking part in the network. The database constructed in this way takes then into account about 90% of the contracts (of those involving shared-cost actions) signed during the Second Framework Program, and 80% of the ones signed during the Third Framework Program[5].

As shown in Table 1 and 2 we have a population of 3,440 participations subdivided in 673 contracts, with 350 contracts in the SF and 323 in the TF. The type of cost, MAR or ECO, identifies the participants that receive up to 100% of the additional cost (MAR, limited to High Education Institutions, HEIs), and the other participants type, to whom the Community reimburses up to 50% of the project costs (ECO).

When we look at the total population, HEIs with a bit more then one fourth of the participations, are playing a quite relevant role both in the SF and in the TF. But, when we look at main contractor figures not only their relevance is less evident, but also their share is going down from the SF to the TF. Therefore, if we make the

[4]The community reimburses up to 50 % of the project costs to companies or institutes that operate a project costing system. Universities, higher education establishments and similar non–commercial bodies receive up to 100 % of the additional costs.

[5]The Third Framework will last up to the end of 1994, then the 80 % represents an estimate of the contracts signed up to March 1st, 1994.

Table 2: Main contractors participations, break down by type of cost

Cost Type	2nd. Framework	3rd. Framework	Total
ECO	278 (79.4%)	263 (81.4%)	541 (80.4%)
MAR	72 (20.6%)	60 (18.6%)	132 (19.6%)
Total	350	323	673

Source: Elaboration EC Data

Table 3: EC contribution in the two frameworks, break down by type of cost (in Million ECUs)

Cost Type	2nd. Framework	3rd. Framework	Total
ECO	275 (73%)	293 (77%)	568 (74%)
MAR	101 (27%)	88 (23%)	189 (26%)
Total	377	380	757

Source: Elaboration EC Data

assumption that projects directed by a HEI are more focused on pre-competitive research, we can highlight a strong and increasing market orientation for the program. To reinforce this observation in Table 3 we show the data concerning the EC contribution. While in the SF the share of EC contribution to HEIs and the share of their participations are about the same value, in the TF they are different due to a decrease in the EC contribution of about 4 points[6]. Therefore, in the TF, HEIs not only have played a less important role in establishing the research efforts, with a subordinate position as the main contractor, but they have also received less funds from the EC, thus weakening furthermore their impact.

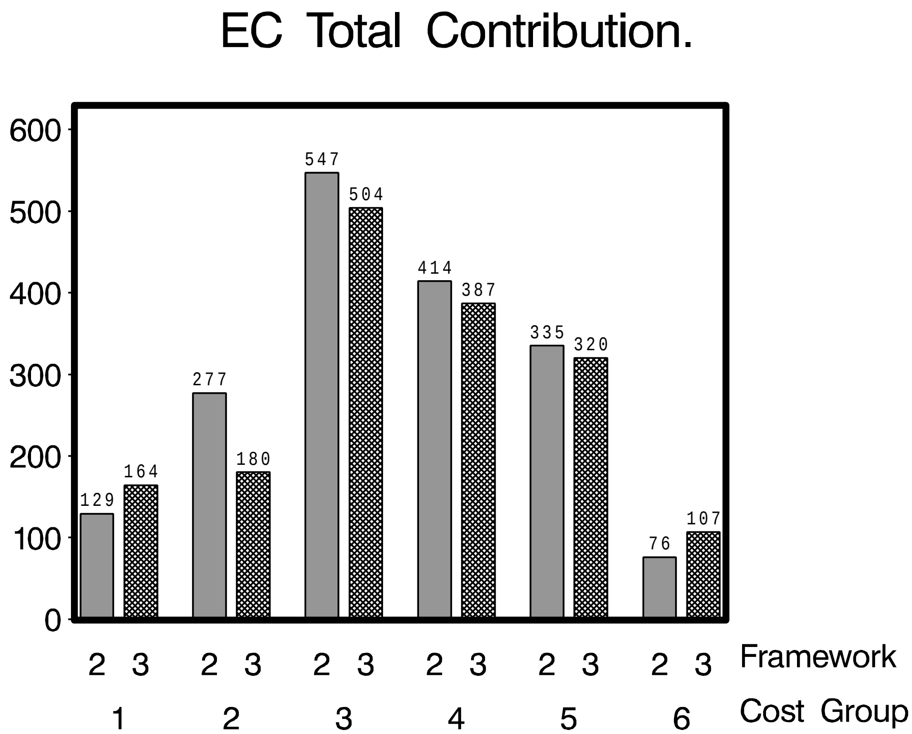
To understand the differences between BE I and BE II we develop a more detailed analysis of the EC contribution. Firstly, we subdivide the variable EC contribution in six categories:

(1) 0 - 25,000 ECU;

(2) 25,000 - 100,000 ECU;

[6] Comparing these figures with the ones of the total framework (see for example Commission, 1994b) we note that the BE programs are characterized by a lower level of HEI participations, and a higher level of HEI funding. Therefore, compared to the aggregate figure, HEIs in the BE program are strong players even if in relative terms they are loosing importance.

Figure 1:



(3) 100,000 - 200,000 ECU;

(4) 200,000 - 300,000 ECU;

(5) 300,000 - 500,000 ECU;

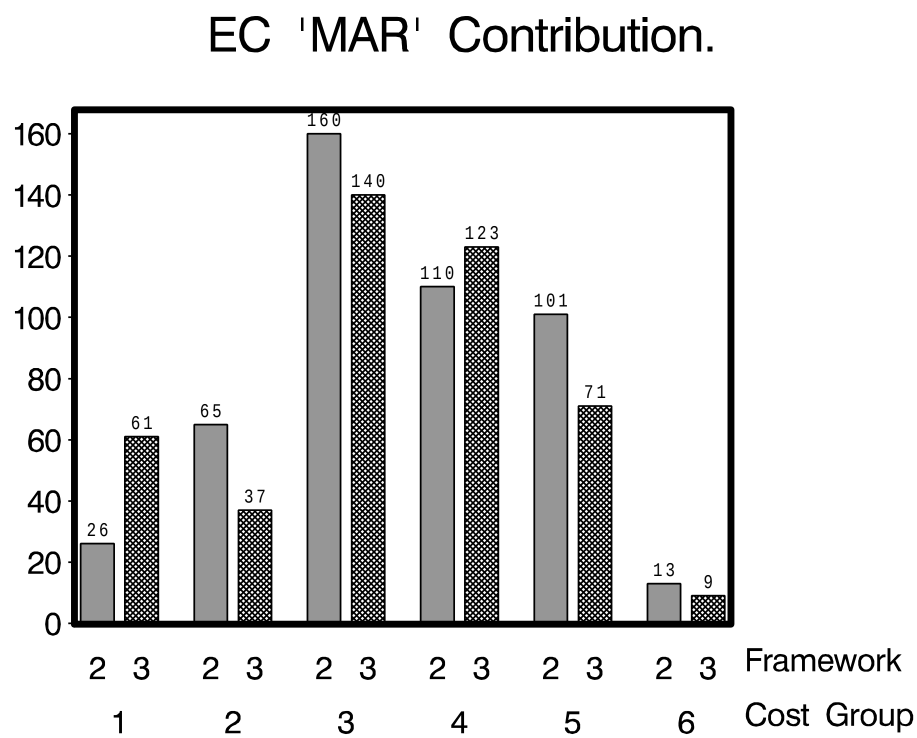
(6) $>$ 500,000 ECU.

We classify the contracts (in this case one for each participation) in relation to these classes. In Figure 1 we show the allocation of EC Total contribution.

Each bar represents the number of contracts present in that class. The distribution is very similar in the two frameworks. The TF, as expected, has slightly lower values than the SF. Only in the first and in the last category it has a higher number of contracts. In particular, the increase of the first class is mainly due to the relevant raise in the number of HEIs contracts.

As Figure 2 illustrates, going from the SF to the TF a larger number of HEIs have participated in a contract with a contribution smaller than 25,000 ECU. While

Figure 2:



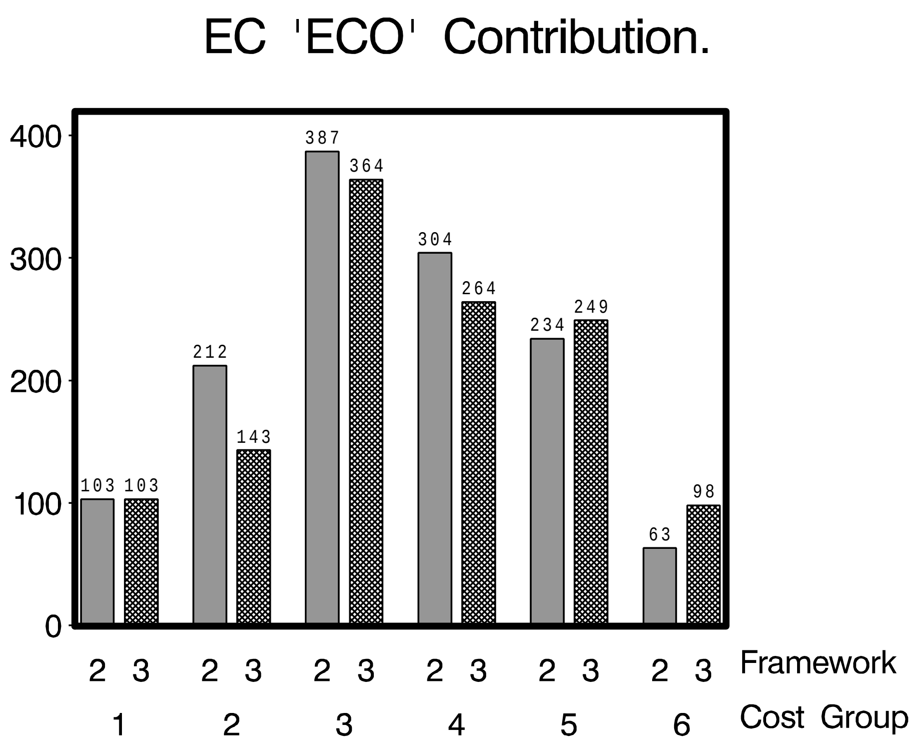
the first category is more than double, the fifth has lost about 30% of the participations.

On the other hand, (see Figure 3), enterprises and research centers have decreased their participation in low budget contract (class 2 has lost a relevant number of contracts) and they have increased their presence in the top class.

Therefore, the increase in the total number of participations with a contract of the sixth category is only caused by this last dynamic feature. Therefore, we can again reconfirm and definitely support the previous observation that HEIs have played a decreasingly important role in the context of the BE programs.

As we highlighted previously, the share of participations and the quota of EC contributions have about the same value in the SF and slightly different in the TF. Although this difference is important for the understanding of a peculiar trend, it is not crucial for the general analysis. Therefore, given the prior description, in our opinion it is equivalent to study the participations or the funding.

Figure 3:



EC 'ECO' Contribution.
400
300
200
100
0
103
103
212
143
387
364
304
264
234
249
63
98
2 3 2 3 2 3 2 3 2 3 2 3
Framework
1 2 3 4 5 6
Cost Group

Table 4: Distribution of the participation type

Participation Type	2nd Framework	3rd Framework	Total
100	350 – 19.7%	323 – 19.4%	673 – 19.5%
200	337 – 19.9%	312 – 18.8%	649 – 18.9%
300	305 – 17. 1%	296 – 17.8%	601 – 17.5%
400	258 – 15.5%	196 – 11.8%	454 – 13.2%
500	178 – 10.0%	135 – 8.1%	313 – 9.1%
Other Contractors	130 – 7.3%	142 – 8.5%	272 – 7.9 %
Sub Contractors	220 – 12.4%	258 – 15.6%	478 – 813.9%
TOTAL	1778 – 100%	1662 – 100%	3440 – 100%

Source: Elaboration EC data

4 Network formation and the hard hub

Up to now we have regarded participants as anonymous institutions without soul and we have ignored completely the network dimension. In this section we try to find a remedy to this shortcoming. Afterwards, we focus our analysis on the formation of networks.

In Table 4 we show the participations distribution according to the position in the network (100 = main contractor, 200 = second contractor, etc). We can highlight two changes in the networks from the SF to the TF.

First, there has been an important increase in the number of subcontractors[7]. Networks have become more branched in small components. Therefore, the number of network linkages with different priority level has increased. At the two extremes are the relationship among contractors at the international level on the one hand, and the linkage between contractors and subcontractors at the local level on the other hand, which was pre-existing to the RTD projects. The increase in subcontractors implies an increased probability of having networks composed by parts of already pre-existing networks. Therefore, networks of the TF are characterized by less genuine novelty.

Second, up to the third contractor there are no big differences between the two frameworks. Instead, the share of participants identified as fourth contractor has strongly decreased in the TF. Hence, in the last framework the networks are com-

[7]Each contractor is entitled to sub–contract part of his/her research to other institutions that become his specific subcontractors

Table 5: Network by number of partners

Number of Partners[a]	2nd Framework	3rd Framework	Total
1	7 – 2.0%	3 – 0.9%	10 – 1.5%
2	22 – 6.3%	7 – 2.2%	29 – 4.3%
3	44 – 12.6%	91 – 28.2%	135 – 20.1%
4	58 – 16.6%	52 – 16.1%	110 – 16.3%
5	94 – 26.9%	54 – 16.7%	148 – 22.0%
6	61 – 17.4%	42 – 13%	103 – 15.3%
> 6	64 – 18.3%	74 – 22.9%	138 – 20.5%
TOTAL	350 – 100%	323 – 100%	673 – 100%

Source: Elaboration EC data.

[a] The number of partners is given by the sum of coordinators, contractors, sub–contractors and contribution ammendments contractors.

posed by a smaller number of contractors. Typically in the TF there are three contractors and a certain number of subcontractors. In general, the TF's networks are then characterized by a lower number of contractors and a larger number of subcontractors.

When we take into account the average networks dimension, the distinction between contractors and subcontractors becomes less important. In Table 5 we show the networks' distribution by dimension (number of partners) in the two frameworks. While the mean number of partners is about five for both frameworks, in the TF slightly less than 50% of the projects are carried out by networks with four or less participants. This is due to the fact that an extremely high number of networks (91) have only three participants. On the other hand, in the SF the networks with five participants are the ones with the highest share. Then, going from the second to the third framework we can highlight a contraction in the dimension of the network, with a polarization of projects within the three–participants network structure.

In general, without taking into account the participants' position in the network, the most recent Framework Program is characterized by networks of a smaller dimension. Moreover, when we look also at the type of participants, the networks of the TF are not only smaller but they are also characterized by a larger amount of subcontractors than by an increasing number of, probably pre-existing, one–to–one relations. Therefore, it seems that this kind of evolution can hinder the process

Table 6: Concentration in the participation

	2nd Framework		3rd Framework		Total	
Single Participation (A)	711 (40 %)	71.2 %	780 (47 %)	75.3 %	1184 34.4 %	69.6 %
Repeated Participation (B)	287	28.8 %	256	24.7 %	516	30.4 %
Total Number of Institutions (C) = (A) + (B)	998		1,036		1,700	
Expanded Participations (D)	1,067 (60 %)		882 (53 %)		2,256 (65.6 %)	
Total Participations (E) = (A) + (D)	1,778		1,662		3,440	

Source: Elaboration EC Data.

of diffusion of new technologies (and of related knowledge bases and capabilities), that is at the base of the European science and technology policy. On the other hand the shrinking of the network dimension can be also due to organizational inefficiencies connected to the management of a large dimension network. So it can be considered as a needed cost –i.e. less institutions involved means less diffusion of new knowledge– to obtain the generation of new technologies –i.e. less partners means easier management and then higher probability of succeeding in the research.

To study the effectiveness of the EC diffusion policy we decided to analyze the concentration in the participation. We assigned a name (A, B, C, etc.) to the various participating institutions and we identified them in the different projects in both frameworks. The result is shown in Table 6. An institution can be involved in RTD projects only one time (single participation), or more times (repeated participation). For the latter type of organization it is then possible to calculate how many times, included the first, it has taken part into a project (expanded participations). The analysis of these variables enables us to compare the two frameworks and to draw some conclusions on the real impact of the EC funding in terms of diffusion policy.

First, the average number of participations for the institutions with repeated participation (D/B) is decreasing. From 3.72 participation in the SF to 3.45 in the TF. In other words the institutions with only one participation obtained in the TF a higher share of contracts (from 40% to 47%). Second, when we consider the two frameworks together we can highlight a higher value for the average number of participations (4.37). This is due to the presence of institutions that are both in the SF and in the TF. Third, there are 334 institutions present at least one time in both frameworks. This group of institutions is characterized by an average number of participations equal to 5.41. Moreover, these 334 institutions, after the first participation, are involved another 1474 times in a project. Considering that in the two frameworks together there are 1740 participations that are repetitions, it follows that the 334 institutions are responsible of 85% of the repetitions (1474 = 0.85 $\times$ 1740). They represent only 19.6% of the population, but they account for 1808 contracts, that is to say 52.6% of the total contracts signed during the two frameworks. Fourth, The 516 institutions with repeated participation in the two frameworks together can be divided in two groups. The first group is formed by the 334 institutions with a mean participation of 5.41 and the second group is formed by the 182 institutions with an average number of participations equal to 1.46 (266/182, where 266 = 1740 - 1474). Finally, the 1700 institutions present in both frameworks can be characterized as follows:

- The ”singles”, formed by 1184 institutions that got only one contract;
- The ”networkers”, formed by 182 institutions that got more contracts, but only in one framework;
- The ”hard hub”, constituted by 334 institutions that got more contracts in both frameworks.

To conclude, we can highlight an effort of the Commission for enlarging the population of institutions involved in RTD projects. In the TF there is, indeed, a larger variety. There are more institutions with a single participation. Therefore we can consider the increase in the number of single participants as a positive indicator of the impact of the EC diffusion policy. However, it is extremely important to stress the relevance of the hard hub. If 19% of the institutions succeed in getting 52% of the contracts it means that more than a half of the EC funds are directed to the same group of institutions. Assuming that these organizations have an extremely high quality, then excluding every kind of bureaucratic inertia and all types of possible industrial lobbying, this implies that the distribution of funds is heavily shaped by the merit criterium and then strongly influenced by cumulative and self reinforcement mechanisms [8]. Therefore, considering both BE programs

[8]Institutions that are succesful in getting funds for their research have a higher probability of

together, the type of involvement enables us to highlight that the Commission is putting a stronger emphasis on the short-term, high performance objectives leaving a secondary role to diffusion policy.

It seems that participants included in the hard hub, networkers and singles, may have significant different behavior within the networks. We will try to provide evidence on this differential behavior by estimating the theoretical model presented above.

5 Empirical results

In this section we estimate the demand functions derived in section 2.

As a deflator we use a real effective exchange rate index against the ECU, since all values are given in this currency unit. As the threat variable, T, we use the average EC contribution for networks of the same size in the same framework.

We assume a loglinear relation for the demand functions derived in the previous section. Total income for each partner of a network is not available, and therefore we have to adopt the assumption that preferences are strongly separable and that the budget constraint depends on the the total budget assigned to the project. As the dependent variable we use total EC contribution.

Equation (6) for the Nash-Cournot case is then formulated as:

$$\text{(12)} \quad \log \text{CONTRIBUTION} = \beta_{i0} + \beta_{i1} \log \text{INCOME} + \beta_{i2} \log \text{SPILL} + \beta_{i3} \log \text{THREAT} + \epsilon_i^N$$

where CONTRIBUTION is the total contribution of the EEC to the network, SPILL is the total contribution to the network minus the contribution for individual i, $THREAT$ is the average EC contribution to networks of equal size and INCOME is total income approximated by the total cost of the project plus SPILL. We add a random perturbation term ϵ_t^N.

Equation (11) for the case of Lindahl equilibrium is formulated as:

$$\text{(13)} \quad \log \text{CONTRIBUTION} = \delta_{i0} + \delta_{i1} \log \text{COST} + \delta_{i2} \log \text{SHARE} + \log \text{THREAT} + \epsilon_i^H,$$

producing exploitable research which improves their probability of joining other projects in the future (see David, 1993, Dasgupta and David, 1994 and Geuna, 1995).

where COST is the total cost of the project, SHARE is the individual cost share (individual contribution received over total contribution), THREAT is the average contribution to networks of similar size and ϵ_i^L is a random perturbation term.

In equation (12) the variables INCOME and SPILL are simultaneously determined in the theoretical model with the EC contribution, and therefore they are correlated with the error term. Similarly in equation (13) the variable SHARE is correlated with the error term. Consistent estimates can be obtained by applying an instrumental–variable estimation procedure. As instruments we chose the total cost of the project (COST) and the threat variable (THREAT).

In table 7 we show the results. The first column presents the pooled regression over both frameworks and types, while the rest of the columns lists separate regressions for both frameworks and types of participants. We show first the results both for the Nash and Lindahl model, and afterwards we will conduct a test to discriminate among these two models.

For the Nash-Cournot equilibrium models, the estimated elasticities are positive and significant in all the cases. This provides support for the joint–product model. Both activities, public common knowledge and private appropriation of knowledge, show elasticities which are less than unity showing that these are normal goods.

For the case of the Nash–Cournot equilibrium the estimated elasticities show an increase in the spill–in effects from the second to the third framework. This result is consistent with the dynamic features described in section 4. The spill–in effects seem also less important for the hub and the networkers, which is consistent with their role as network spanners. Single participants, on the other hand, receive the highest proportion of spill-ins within the networks.

In the case of the Lindahl specification, the negative coefficient of the SHARE variable is consistent with the Slutzky equation for the case of a Lindahl equilibrium. There is also a significant increase in the absolute value of this coefficient from the second to the third framework for the hub and the networkers, and a decrease for the singles. This is consistent with the results obtained for the Nash equilibrium.

It is interesting to discriminate between these two models, which provides evidence on the cooperative behavior within the networks. We conduct a non–nested J-test for discriminating between the models[9] The methodology consists of two new regressions, which are constructed as follows: First a regression is run on the Lindahl model, and then the predicted values of this regression is added as a new explanatory variable to the Nash model. If the estimated coefficient for this new

[9]See MacKinnon, White and Davidson (1983) on the methodology of this test.

Table 7: Nash-Cournot and Lindahl coalition models. Dependent Variable: total contribution of the EU

	Pooled[a]	Second Framework			Third Framework		
	Regression	Hard Hub	Networkers	Singles	Hard Hub	Networkers	Singles

Nash equilibrium

Intercept	0.003[b]	0.77	1.23[b]	0.56[b]	0.76	0.50[b]	-0.07[b]
	(0.12)	(0.30)	(0.71)	(0.30)	(0.20)	(0.39)	(0.37)
Income	0.59	0.61	0.54	0.58	0.59	0.59	0.59
	(0.01)	(0.02)	(0.04)	(0.01)	(0.02)	(0.02)	(0.01)
Spill	0.23	0.17	0.14	0.28	0.28	0.41	0.32
	(0.02)	(0.04)	(0.18)	(0.03)	(0.04)	(0.06)	(0.06)
Threat	0.17	0.16	0.23	0.10	0.08	-0.04[b]	0.09[b]
	(0.02)	(0.04)	(0.16)	(0.05)	(0.04)	(0.09)	(0.07)

Lindahl equilibrium

Intercept	-0.15[b]	1.06[b]	2.14[b]	1.07[b]	1.11	-0.35[b]	-1.34
	(0.22)	(0.67)	(1.35)	(0.81)	(0.40)	(0.76)	(0.59)
Cost	0.45	0.45	0.31	0.55	1.45	0.53	0.44
	(0.02)	(0.03)	(0.10)	(0.06)	(0.04)	(0.12)	(0.07)
Share	-0.41	-0.40	-0.27	-0.52	-0.44	-0.59	-0.40
	(0.03)	(0.05)	(0.13)	(0.08)	(0.05)	(0.16)	(0.10)
Threat	0.54	0.46	0.53	0.34	0.45	0.46	0.63
	(0.03)	(0.06)	(0.16)	(0.11)	(0.06)	(0.17)	(0.12)

All the coefficients are significant at a 5 % level unless otherwise noted.

[a] All the data for both frameworks and type of participants pooled.
[b] Not significantly different from zero at a 5 % level.

Table 8: J-Test for discriminating between Nash and Lindahl behavior

	Hypothesis 1			Hypothesis 2		
	α_L	t-ratio	Conclusion	α_N	t-ratio	Conclusion
Second Framework						
Hard Hub	-0.49	-2.3	Reject	1.60	53.0	Reject
Networkers	-0.95	-1.7	Fail to reject	1.77	18.1	Reject
Singles	-0.69	-3.3	Reject	1.39	27.4	Reject
Third Framework						
Hard Hub	-0.05	-0.3	Fail to reject	1.15	38.6	Reject
Networkers	0.42	0.6	Fail to reject	0.94	10.6	Reject
Singles	0.04	0.2	Fail to reject	1.23	39.1	Reject

variable, which we call α_L, turns out to be significantly different from zero, then the Lindahl model is supported (Hypothesis 1). If it is not significantly different from zero then there is evidence against the Lindahl model. The second regression consists of this procedure reversed, that is, a regression is run with the original Lindahl model plus the predicted values of the Nash model, obtaining a new coefficient α_N (Hypothesis 2). We conduct this test for the 6 models, that is for the two frameworks and the three types of participants. The results are reported in table 8.

Our data seem to support a non–cooperative behavior in the interaction of networkers, especially in the third framework. For that framework the Nash model cannot be rejected while the Lindahl model is rejected in all instances.

6 Concluding remarks

In this paper we have investigated the dynamics of network formation within the Brite-Euram program. This is a program implemented by the European Union to foster industry–university R & D research with the objective of improving the competitiveness of European industry.

We unveiled some dynamic features for the role of the hub of the networks, main contractors, and the behavior of followers. We found that a small group of institutions account for most of the participations within the networks, but that going from the second to the third framework of projects, the presence of subcontractors and single participants increases. Therefore the most reputed institutions are receiving most of the funding, but at the same time an increasing number of participants are receiving spill–ins from the hub.

This interpretation is reinforced by a testable model of coalition formation and spill-ins of public knowledge within the coalitions. We model networks as coalitions formed with the objective of jointly producing private knowledge and common knowledge which is public within the networks. In this kind of model, we find that institutions that account for most participations receive smaller spill-ins than institutions that participate many times but only in one framework or institutions that participate only once. Spill–ins also seem to increase from the second to the third framework.

These results may have important policy implications related to the long–term results pursued by EU funding, and the short–term results of increasing competitiveness for European industries. The cohesion objectives in principle hinder short–term results, but through an indirect way by powering the hub of the networks, increased spill–ins are being generated to a larger number of institutions.

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Appendix: The BRITE–EURAM family of research programs

The first BRITE-EURAM program was built on the experience and the achievements emerging from the separate BRITE (Basic Research in Industrial Technologies for Europe) and EURAM (European Research on Advanced Materials) programs. In particular, under BRITE (1985-1988) 215 shared-cost research projects were developed. The European Commission (henceforth EC) allocated 180 million ECUs (MECU) to that program. The most relevant aim of the program was to develop the applications of new technologies and new materials in traditional industrial sectors. During the same span of time under the EURAM (1986-1989) program the EC approved 91 projects, for about 30 MECU. The program had as its main goal to stimulate the development of research in new materials (CEC, 1992a: p.65).

The BRITE-EURAM I (1989-1992) program (henceforth BE I) is then the aggregation and extension of these two programs. It was approved by the Council of Ministers on March, 1989. It was budgeted under the Second Framework Program for about 500 MECU. The main aim of this 4-year program was to improve the competitiveness of European manufacturing industry in the world market. Moreover, the following strategic objectives were also indicated: (i) to foster trans-frontier collaboration in strategic industrial research, (ii) to support the transfer of technology across Community frontiers and between sectors, particularly those with many small and medium enterprises (SME), (iii) to underpin the process of European cohesion (Commission, 1993: pp.9-16). Even if the program was devoted to pre-competitive research it was characterized, more than the previous two, by market-oriented activity. The Program covered 5 R &D areas:

(1) Advanced Materials Technology,

(2) Design Methodology and Assurance,

(3) Application of Manufacturing Technologies,

(4) Technologies for Manufacturing Processes,

(5) Aeronautics.

To assist SMEs, the program included not only shared-cost research contracts, but also concerted actions and feasibility awards [10]. Emphasis on SMEs and market orientation of research distinguished the BE I program from the previous two.

[10] *Concerted Actions* are projects to support the coordination of broad–based, pan–European col-

On September, 1991, within the Third Framework Program, the Industrial and Material Technology program (BRITE-EURAM II) was approved for the period 1991- 1994 by the Council of Ministers. The operating budget of the program was approximately 670 MECU. This program resulted from the merging of the two programs BE I and Raw Materials and Recycling (1990-1992) [11]. Following the previous program, the basis of BRITE-EURAM II (henceforth BE II) was the revitalization of European manufacturing industry. Its main aims were: (i) to increase the competitiveness of European industry in the face of strong international challenges, particularly in strategic sectors of advanced technology; (ii) to strengthen European economic and social cohesion consistent with the pursuit of scientific and technical excellence; (iii) to increase implementation of advanced technologies by SMEs; (iv) to increase involvement of manufacturing SMEs in European RTD thereby developing links with other enterprises (Commission, 1992b, pp.7-11).

The program was characterized by a focus on advanced technology, the relevance given to the process of European economic and social cohesion and by the particular support for the SMEs' participation [12]. The program included three main technical areas –i.e. areas of research– which were:

(1) Materials & Raw Materials:

  (1.A) Raw Materials and Recycling,

  (1.B) New and Improved Materials and Their Processing;

(2) Design & Manufacturing:

  (2.A) Design,

  (2.B) Manufacturing and Engineering;

(3) Aeronautics.

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laborative research activities in promising new technologies with the benefit of real added value as a result of cross–border collaboration. The Commission supports the coordination costs, but not the research cost. *Feasibility Award* is a special type of contract, available to SMEs, that covers up to 75 % of the costs of research undertaken within nine months (subject to a maximum of 30,000 ECUs) to establish the feasibility of a concept, process or material for a collaborative Brite–Euram project.

[11] During the two years of life of the RAW program 69 shared–cost research projects for about 23 MECU were carried out.

[12] The *Cooperative Research Action for Technology (CRAFT)* is designed to provide enterprises, especially SMEs not having their own research facilities, with the possibility to contract outside research institutes to carry out research on their behalf (ibid: p.13).

Industrial enterprises, universities, research centers and other institutions have taken part into the program through five different schemes of support. They are: (1) shared-cost collaborative research projects. In particular, about 90% of the available Community research budget was ascribed to the two sub-categories Industrial Research (80%) and Focused Fundamental Research (10%); (2) Concerted Actions already implemented in BE I; (3) Accompanying Measures, among which, with a particular importance, the previously mentioned Feasibility Awards; (4) Co-operative Research Actions for Technology; and (5) Targeted Research Actions, which imply that for specific subjects of common interest –e.g. environmentally friendly technologies and flexible and clean manufacturing– industrial research projects may be grouped together and be subject to special coordination to ensure synergy between the separate projects. What is interesting to grasp from the previous description is the continuity between the two BRITE-EURAM programs. Indeed, BE II can be seen as a further step in the process of definition of a European program. Due also to the Maastricht Treaty and to the feed-back from the previous program, BE II turned out to be a program with a clearer strategic orientation and an improved and enlarged variety of schemes of support.

The new research and technological development program in the field of industrial and materials technologies BRITE-EURAM III (1994-1998) (henceforth BE III) was approved by the Council of Ministers on July 1994. The operating budget of the program is about 1,700 MECU. The concern with the competitive position of the European manufacturing industry is still at the hearth of the program. In particular, competitiveness is seen as the most effective means of maintaining and even increasing employment. Due to the latest economic recession (1990–93) and due to the increased concern about pollution level, the program aims to stimulate industry's capacity to "develop technology for human-centered production system taking account of human factors and based on clean technologies" (Commission, 1994a: p.7). Three specific objectives are identified. They are: (i) "in the short term, priority should be assigned to research for the adaptation of existing technologies, or for the development of new technologies ... particularly in sectors where the level of technology is lower; SMEs in these sectors account for a large proportion of European industry"; (ii) "in the medium term, research will focus on industries which are already developing innovative technologies and strategies allowing better use of human resources while endeavoring to reduce the adverse environmental impact of production"; (iii) "in the long term, research will focus on new technologies for the production and the design of products which allow new industries or markets to be created in a context of sustainable growth" (ibid: p.8). The program will include three main technical areas –i.e. areas of research– which are:

(1) Production technologies for future industries;

(2) Technologies for product innovation;

(3) Technologies for transport means.

While the first two, with different name and different sub-classes, are similar to the first two areas of BE II, the third one has been broadened to include not only aeronautics, but also other technologies for transportation. The program will be implemented through the same schemes of support used in BE II. The only new tool is the Pre-Normative Research Project. It is linked to the fulfillment of the general goal of the Fourth Framework Program of supporting the other Community policies through pre-normative research. Finally, the observation we made for the evolution of BE II in comparison with BE I, can be also made for the new program versus the previous one. What we want to underline here is the existence of an evolution process which can be linked to the change of external economic and non-economic factors. However, the various modifications are not modifying a group of consolidated features of what we can call the BRITE-EURAM family.